

DESCRIPTION

ANALOG ELECTRONIC TIMEPIECE

5 TECHNICAL FIELD

[0001]

The present invention relates to an analog electronic timepiece capable of preventing deviation of time displayed thereon even when an impact is applied thereto, and more particularly, to an analog electronic timepiece capable of preventing irregular motions of hands thereof when the timepiece is dropped or an impact is applied to the timepiece.

15 BACKGROUND ART

[0002]

Conventionally, an analog electronic timepiece such as a wrist watch, etc., has a structure in which have time hands provided on a display unit rotate. The current time is recognized by the rotational positions of an hour hand, a minute hand, and a second hand that are the hands. Since such a wrist timepiece is small-sized, the visibility of the hands and accuracy of the displayed time are demanded. Especially in a wrist watch, downsizing and low power consumption are demanded. To meet this demand, small thin hands must be used. Therefore, the visibility has been poor.

[0003]

If, for example, a thick second hand is used to improve the visibility, a weight of the second hand becomes heavy, causing a concern that the displayed time is deviated with only a small impact, that is, degradation of anti-shock property of the timepiece. To improve such an

anti-shock property, a retentive power of a step motor that is a driving source should be increased. However, this method can not be employed because the power consumption during driving increases.

5 [0004]

Mechanisms to cancel the deviation of the displayed time when an impact is applied externally are disclosed in, for example, Patent Documents 1 and 2 below. The technique disclosed in Patent Document 1 prevents a deviation of the
10 displayed time by braking the motion of a rotor of a step motor when the rotor detects a counter electromotive force generated while being jolted due to an impact. The technique disclosed in Patent Document 2 facilitates detection of an impact by periodically amplifying a counter
15 electromotive force generated when the impact is detected and the level of this counter electromotive force.

[0005]

Patent Document 1: Japanese Patent Application Laid-Open Publication No. S65-110073

20 Patent Document 2: Japanese Patent Application Publication No. S61-61356

DISCLOSURE OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

25 [0006]

However, in recent wrist watches, power-generating timepieces have become prevailing. Accordingly, batteries (power sources) have shifted to lower capacity batteries even for wrist watches that respectively include a battery.
30 In addition, down-sizing of wrist watches have been promoted. Therefore, the above conventional techniques may fail to prevent the deviation of the displayed time when an impact is applied to a timepiece.

[0007]

In view of the above problems, it is an object of the present invention to provide an analog electronic timepiece capable of preventing a deviation of the displayed time thereof even when an impact is applied to the timepiece, while down-sizing the timepiece and lowering a capacity of a battery in the timepiece.

MEANS FOR SOLVING PROBLEM

10 [0008]

To solve the above problems and to achieve the object, an analog electronic timepiece according to the invention of claim 1 includes a driving signal supplying unit configured to generate and supply a reference signal for clocking; an impact detecting unit configured to detect an impact applied externally, based on a counter electromotive force of a step motor that drives hand motion of time hands; and a controlling unit configured to control to drive the step motor using an intermittent driving pulse based on the reference signal supplied from the driving signal supplying unit when the time hands are in a hand-driven state, and to control to brake the step motor when an impact is detected by the impact detecting unit while the time hands are in a non-hand-driven state.

25 [0009]

Moreover, in the invention according to claim 1, the analog electronic timepiece according to the invention of claim 2 includes a chopper-amplifier unit configured to amplify a counter electromotive force generated by the step motor with a predetermined amplification ratio and at a predetermined pulse period when an impact is applied externally to the analog electronic time piece. The impact detecting unit is provided with a predetermined threshold,

and is configured to detect an impact based on whether a signal level amplified by the chopper-amplifier unit at the pulse period exceeds the threshold.

[0010]

5 Furthermore, in the invention according to claim 2, the analog electronic timepiece according to the invention of claim 3 has the chopper-amplifier unit in which the pulse period is set to a value corresponding to a weight and a moment of inertia of the time hands.

10 [0011]

 Moreover, in the invention according to claim 2 or 3, the analog electronic timepiece according to the invention of claim 4 has the chopper-amplifier unit in which the pulse period is set to a value corresponding to a power
15 source voltage.

[0012]

 Furthermore, in the present invention according to claim 2 or 3, the analog electronic timepiece according to the invention of claim 5 has the chopper-amplifier unit in
20 which a chopper-width is set to 30.5 μ s.

[0013]

 Moreover, in the invention according to any one of claims 1 to 3, the analog electronic timepiece according to the invention of claim 6 has the controlling unit that
25 includes a lock pulse output unit configured to control the step motor when the impact is detected. The lock pulse output unit outputs a lock pulse for a term corresponding to a power source voltage supplied to the step motor.

[0014]

30 Furthermore, in the invention according to claim 6, the analog electronic timepiece according to the invention of claim 7 has the lock pulse output unit that is configured to output a continuous pulse having a same phase

as that of the driving pulse generated when an impact is applied.

[0015]

Moreover, in the invention according to claim 7, the
5 analog electronic timepiece according to the invention of
claim 8 has the lock pulse output unit that outputs the
lock pulse that includes at least a lock term for
outputting the continuous pulse and a stable section for
outputting an inversed pulse after the lock terms has
10 passed.

[0016]

Furthermore, in the invention according to any one of
claims 1 to 3, 7, and 8, the analog electronic timepiece
according to the invention of claim 9 has the controlling
15 unit that includes a load compensating unit configured to
detect rotation of a rotor based on detection of a counter
electromotive force from the pulse motor soon after the
output of the driving pulse.

[0017]

Moreover, in the invention according to any one of
20 claims 1 to 3, 7, and 8, the analog electronic timepiece
according to the invention of claim 10 has the controlling
unit that is configured to provide stable terms
respectively for starting the rotor of the pulse motor from
25 a stationary stable point thereof before outputting the
driving pulse, and for returning the rotor of the pulse
motor to the stationary stable point thereof after
outputting the driving pulse.

[0018]

Furthermore, in the invention according to any one of
30 claims 1 to 3, 7, and 8, the analog electronic timepiece
according to the invention of claim 11 has the impact
detecting unit constituted of inverters that operate based

on supply of a source power that is adapted to supply a constant voltage without depending on the power source voltage.

[0019]

5 Moreover, in the invention according to claim 9, the analog electronic timepiece according to the invention of claim 12 has the impact detecting unit that includes an impact detecting resistor configured to detect a counter electromotive force from the pulse motor at the time of the
10 impact. The load compensation unit includes a load compensating resistor configured to detect a counter electromotive force from the pulse motor soon after the driving pulse is output.

[0020]

15 Furthermore, in the invention according to claim 12, the analog electronic timepiece according to the invention of claim 13 has the impact detecting resistor in which a resistance value is set at the minimal resistance value with which the rotation of the pulse motor is detected.

20 [0021]

 Moreover, in the invention according to claim 12, the analog electronic timepiece according to the invention of claim 14 has the impact detecting resistor for which setting is set for each type of timepiece.

25 [0022]

 Furthermore, in the invention according to any one of claims 12 to 14, the analog electronic timepiece according to the invention of claim 15 includes a detecting resistor used commonly for the impact detecting resistor and the
30 load compensation resistor. The impact detecting unit and the load compensating unit are configured to detect an impact and load compensation using the detecting resistor.

[0023]

Moreover, in the invention according to any one of claims 7, 8, and 12 to 14, the analog electronic timepiece according to the invention of claim 16 has the lock pulse output unit that is configured to secure an output term of the lock pulse when the lock pulse is input at a time of a logic frequency adjustment executed at predetermined intervals.

[0024]

Furthermore, in the invention of any one of claims 7, 8, and 12 to 14, the analog electronic timepiece according to the invention of claim 17 includes a battery detection controlling unit configured to make the output of the lock pulse precede when the lock pulse is output from the lock pulse output unit at a time of detection of the power source voltage executed at predetermined intervals.

EFFECT OF THE INVENTION

[0025]

An analog electronic timepiece according to the present invention is capable of preventing a deviation of displayed time even when an impact is applied to the timepiece. Particularly, the timepiece is capable of preventing the deviation of the displayed time by suppressing a motion of hands thereof caused when an impact is applied to the timepiece even if a capacity of a battery is lowered and a main body of the timepiece is down-sized.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

[Fig. 1] Fig. 1 is a block diagram of a configuration of an analog electric timepiece according to a first embodiment of the present invention;

[Fig. 2] Fig. 2 is a block diagram of a regulator

circuit;

[Fig. 3] Fig. 3 is a circuit diagram showing a configuration of a lock pulse counter;

5 [Fig. 4] Fig. 4 is a timing chart showing a control of a BD controlling circuit;

[Fig. 5] Fig. 5 is a timing chart showing a state of a signal at each unit respectively in a hand-driven state and a non-hand-driven state of a second hand;

10 [Fig. 6] Fig. 6 is a timing chart showing a state of a signal at each unit in the hand-driven state;

[Fig. 7] Fig. 7 is a timing chart showing a state of a signal at each unit when a light impact has occurred in the non-hand-driven state;

15 [Fig. 8] Fig. 8 is a timing chart showing a state of a signal at each unit when a heavy impact has occurred in the non-hand-driven state;

[Fig. 9] Fig. 9 is a waveform diagram of a current detected when a light impact is applied;

20 [Fig. 10] Fig. 10 is a waveform diagram of a current obtained by chopper amplification when a light impact is applied;

[Fig. 11] Fig. 11 is a chart showing an example of settings of a period and a chopper width in the chopper amplification;

25 [Fig. 12] Fig. 12 is a chart for explaining a relation between a power source voltage and a time deviation in the configuration according to the present invention;

30 [Fig. 13] Fig. 13 is a chart for explaining the relation between the power source voltage and the time deviation in the configuration according to the present invention; and

[Fig. 14] Fig. 14 is a block diagram of a configuration of an analog electronic timepiece according

to a second embodiment of the present invention.

EXPLANATIONS OF LETTERS OR NUMERALS

[0027]

- 5 100 analog electronic timepiece
- 101 driving signal supplying unit
- 102 controlling circuit
- 103 driving circuit
- 104 impact detecting circuit
- 10 105 step motor
- 106 second hand
- 111 oscillating circuit
- 112, 113, 114 frequency divider circuit
- 115 waveform shaping circuit
- 15 116 DF adjusting circuit
- 117 BD controlling circuit
- 118 chopper-amplification waveform shaping circuit
- 121 motor driving pulse waveform shaping circuit
- 122 lock pulse controlling circuit
- 20 123 lock pulse counter
- 124 lock pulse waveform shaping circuit
- 125 load compensation controlling circuit
- 126 impact detecting resistor controlling circuit
- 131, 132, 133, 134, 135, 136, 142, 144, 153, 154
- 25 transistor
- 141, 143 impact detecting resistor
- 145, 146 inverter
- 147, 148 level converting circuit
- 149, 157 OR circuit
- 30 150 AND circuit
- 151, 152 load compensation detecting resistor
- 155, 156 inverter
- 161 coil

161a pole piece
162 rotor
163, 164 gear
AA, BB signal line

5

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0028]

Embodiments of an analog electronic timepiece according to the present invention will be explained in detail below with reference to the accompanying drawings. The embodiments are not intended to limit the present invention.

[0029]

(First Embodiment)

15 Fig. 1 is a block diagram of a configuration of an analog electronic timepiece according to a first embodiment of the present invention. An analog electronic timepiece 100 is constituted of a driving signal supplying unit 101, a controlling circuit 102, a driving circuit 103, an impact
20 detecting circuit 104, and a step motor 105. In the drawings, numerals such as S1, S2, etc. are provided to signals output from each unit.

[0030]

The driving signal supplying unit 101 supplies a
25 driving signal for driving to rotate the time hands provided to a wrist timepiece as the analog electronic timepiece 100. The step motor 105 drives stepwise a second hand 106 at a period of one second. The states where the second hand 106 is being driven and is not being driven are
30 respectively referred to as "hand-driven state" and "non-hand-driven state". The driving signal supplying unit 101 has an oscillating circuit 111 that outputs a reference oscillating signal S1 (32,768 Hz); frequency divider

circuits connected in a multi-stage configuration 112, 113, 114 to obtain necessary frequency-dividing outputs S2, S3, S4 based on inputting of the oscillating signal S1 from the oscillating circuit 111; and a waveform shaping circuit 115
5 that shapes the waveform of the frequency-dividing output S4 (pulses of ten seconds each) of the frequency divider circuit 114.

[0031]

The driving signal supplying unit 101 also has a DF
10 adjusting circuit 116 that outputs a signal S17 that adjusts logic frequency (DF-adjustment) at a period according to an output S5 of the waveform shaping circuit 115; a BD controlling circuit 117 that executes control when detection of an impact is overlapped on detection of a
15 power source voltage of a driving battery, based on the frequency-dividing outputs S2, S4 respectively of the frequency divider circuits 112, 114; and a chopper amplification waveform shaping circuit 118 that that generates a pulse signal chopper-amplified to detect
20 precisely a detection signal of an impact generated during the non-hand-driven state of the second hand 106 based on inputting of a frequency-dividing output S8 of the frequency divider circuit 112 and a controlling signal S12 of a lock pulse output from a lock pulse controlling
25 circuit 122.

[0032]

The controlling circuit 102 is constituted of, for example, a random logic, and has a motor driving pulse waveform shaping circuit 121 that outputs a controlling
30 signal S11 that disables the lock pulse controlling circuit 122 during a normal pulse term during which the frequency-dividing output S3 (pulses of one second each) of the frequency divider circuit 113; the lock pulse controlling

circuit 122 that is input with the controlling signal S11 output from the motor driving pulse waveform shaping circuit 121 and an impact detecting signal S33 detected by the impact detecting circuit 104, and that outputs the
5 controlling signals S12, S13 of an output of the lock pulse that prevent the deviation of the second hand of the step motor 105 when an impact has been detected; a lock pulse counter 123 constituted of a counter that sets an output term based on the controlling signal S13 of the lock pulse
10 output from the lock pulse controlling circuit 122 and the frequency-dividing output S5 (pulses of ten seconds each) after shaping the waveform thereof output from the waveform shaping circuit 115; a lock pulse waveform shaping circuit 124 that shapes the waveform of a lock pulse S14 output
15 from the lock pulse counter 123; a load compensation controlling circuit 125 that detects whether a rotor 162 of the step motor 105 has rotated during a term immediately after a driving pulse has been supplied to the step motor 105 in the hand-driven state of the second hand 106; and
20 impact detecting resistor controlling circuit 126 that stops the detection of impacts in the hand-driven state of the second hand 106 and detects impacts in the non-hand-driven state thereon.

[0033]

25 The driving circuit 103 has signal lines AA, BB that supplies driving pulses S18, S19 for driving the second hand 106 every one second from the controlling circuit 102 to the step motor 105. The signal line AA is provided with transistors 131, 132 such as MOS-FET, etc. The signal line
30 BB is provided with transistors 133, 134 that receive driving pulses S20, S21 and supply those pulses S20, S21 to a coil 161 of the step motor 105. The signal line AA is provided with a transistor 135 in parallel to the

transistors 131, 132. The signal line BB is provided with a transistor 136 in parallel to the transistors 133, 134. These transistors 135, 136 supply to the signal lines AA, BB a pulse signal S10 for detecting an impact supplied by the chopper-amplification waveform shaping circuit 118 in the non-hand-driven state. These transistors 135, 136 are provided in parallel to the transistors 131, 132, 133, 134 as drivers outputting the driving pulses S18, S19, S20, S21 and, because these transistors 135, 136 are rather small transistors, an increase of power consumption can be suppressed for the gate capacities thereof are small.

[0034]

The impact detecting circuit 104 has an impact detecting resistor 141 and a transistor 142 both connected with the signal line AA and an impact detecting resistor 143 and a transistor 144 both connected with the signal line BB. The value of resistance of the impact detecting resistor 141 is set at the minimum value (for example, in a range of 40 k Ω to 160 k Ω) for which the fact that the rotor 162 of the step motor 105 has been rotated due to an impact can be detected. Though the sensitivity can be increased by increasing the value of resistance of the resistor 141, at the same time, even a small impact can be detected. Therefore, an appropriate value needs to be set. The value of resistance of this impact detecting resistor 141 can be set or adjusted at an appropriate value for each type of timepiece (for example, the weight of the second hand 106, the moment of inertia (referred to as "biased weight"), and the size) or each individual timepiece when the timepieces are shipped. Thereby, an output of the lock pulse generated when an impact has been detected unnecessarily can be suppressed.

[0035]

The transistors 142, 144 is controlled by a controlling signal S15 of the impact detecting resistor controlling circuit 126 such that the transistors 142, 144 can detect an impact in the non-hand-driven state. An
5 impact received in the non-hand-driven state of the second hand 106 is represented as a current waveform on the signal lines AA, BB due to a counter electromotive force of the step motor 105. At this point, a chopper-amplified current waveform (impact detecting signal) is input into inverters
10 145, 146 through signals S22, S23 on an impact detecting line. The inverters 145, 146 compare the input impact detecting signals S22, S23 with a pre-determined threshold value, and when the levels of the impact detecting signals S22, S23 exceed the threshold value, outputs signals S28,
15 S29 (also referred to as "impact detecting signal") indicating a impact-detected state.
[0036]

Level converting circuits 147, 148 outputs to an OR circuit 149 signals S30, S31 obtained by level-converting
20 these impact detecting signals S28, S29. The OR circuit 149 outputs the signals S30, S31 to an AND circuit 150 as an output S32. The AND circuit 150 is input with this signal (impact detecting signal) S32, and the controlling signal S15 of the impact detecting resistor controlling
25 circuit 126; and outputs only the impact detecting signal S33 detected in the non-hand-driven state to the lock pulse controlling circuit 122. The signal lines AA, BB are connected with load compensation detecting resistors 151, 152 and transistors 153, 154, and a load compensation
30 detecting term is controlled by a signal S16 of the load compensation controlling circuit 125. When the load is compensated, outputs S24, S25 of the inverters 155, 156 connected respectively with the signal lines AA, BB are

output to the load compensation controlling circuit 125 as an output S26 through an OR circuit 157. Reflecting the result of the output S26, a signal S27 is output to the motor driving pulse waveform shaping circuit 121.

5 [0037]

The step motor 105 is constituted of the rotor 162 capable of rotating at a pole piece 161a part of the coil 161; and a plurality of gears 163, 164 interlocked with the rotor 162. The second hand 106 is attached to the final-
10 stage gear 164.

[0038]

Fig. 2 is a block diagram of a regulator circuit. The timepiece of the present invention supplies using a regulator circuit 200 a power source voltage VSS to the
15 inverters 145, 146 of the impact detecting circuit 104 as a constant voltage Vreg. Thus, the inverters 145, 146 can stably detect an impact preventing variation of the sensitivity without depending on the power source voltage. The inverters 145, 146 is set such that, when the level of
20 the impact detecting signal is varied around the threshold value, the inverters 145, 146 lower the ability thereof because the power consumption is increased. Because the detection is executed using the voltage level even with this setting, the detected level and the sensitivity are
25 not influenced.

[0039]

Fig. 3 is a circuit diagram showing a configuration of the lock pulse counter. The lock pulse counter 123 secures an output term of a lock pulse such that the output term of
30 the lock pulse does not become short during the logic frequency adjustment (DF adjustment) executed at a pre-determined period (for example, every ten seconds). The lock pulse counter 123 has an AND circuit 306 that is input

with a frequency-dividing output S7 provided from the frequency divider circuit 112, and is input with four counters F1 to F4 for frequency-division connected in tandem, an output S40 of the final-stage counter F4 ,and
 5 the output S5 for every DF adjustment from the waveform shaping circuit 115; an inverter 307 that inverts the output S5 of the waveform shaping circuit 115; an AND circuit 308 that is input with the output S40 of the final-stage counter F4 and the output S5 of the waveform shaping
 10 circuit 115 that have been inverted by the inverter 307; and an OR circuit 309 that is input with a counter F5 for counting an output of the AND circuit 306, an output S41 of the counter F5, and an output of the AND circuit 308.
 [0040]

15 For the output S40 of the counters F1 to F4, the output S41 of the counter F5 outputs a long-term lock pulse. That is, the output S41 of the counter F5 is used when the DF adjustment is executed and the output S40 of the counters F1 to F4 is used when the DF adjustment is not
 20 executed, and, thereby, an output term of a lock pulse is prevented from being shortened when the DF adjustments are executed every pre-determined period. That is, the output S14 of the OR circuit 309 secures a specific term as an output term of the lock pulse. The lock pulse is provided
 25 to the step motor 105 after shaping of the waveform thereof through the lock pulse waveform shaping circuit 124.
 [0041]

Fig. 4 is a timing chart showing a control of the BD controlling circuit. The BD controlling circuit 117
 30 periodically detects ((a) in Fig. 4) that the power source voltage has been lowered in the normal driving of hands, based on the timing of the frequency-dividing outputs S4, S6 of the frequency divider circuits 112, 114. When a lock

pulse ((b) in Fig. 4, and the signal S34 in Fig. 1) has been output from the lock pulse controlling circuit 122 due to detection of an impact (time t1), the BD controlling circuit 117 stops the detection of the power source voltage. As shown in (c) of Fig. 4, the BD controlling circuit 117 retains a condition for the term from the time t1 to a time t2 at which the output of the lock pulse is stopped, and resumes at a desired time (time t3) after the time t2 the detection of the power source voltage that has been stopped. The normal detection interval of the power source voltage is sufficiently longer than the timing described in (a) of Fig. 4.

[0042]

The operation according to the above configuration will be described. Fig. 5 is a timing chart showing the state of a signal at each unit respectively in a hand-driven state and a non-hand-driven state of a second hand. As shown, the second hand has alternately non-hand-driven states and hand-driven states. When a non-hand-driven state is switched to a hand-driven state, for the controlling circuit 102, the output S18 to the transistor 131 is changed from [H] to [L] and the output S19 to the transistor 132 is not changed and remains at [L]. As shown, the output S10 of the chopper-amplification waveform shaping circuit 118 outputs periodic pulses for chopper-amplification in the non-hand-driven state. The signal lines AA, BB are activated to [H] for the terms depicted by solid lines in Fig. 5 and are OPEN for the terms depicted by dotted lines.

[0043]

For the controlling circuit 102, the state of the output S20 to the transistor 133 is switched being triggered by the output of a driving pulse to a state where

[H] and [L] alternate periodically, after a pre-determined time period (T2: for example, 1 ms) has passed since the state of the output S20 has become [H]. The state of the output S21 to the transistor 134 is also switched triggered by the driving pulse, from a [L] state to a state where [H] and [L] alternate periodically. The impact detecting resistor controlling circuit 126 prohibits impact detection using the output S15, throughout the hand-driven state (impact detection prohibited section T0). This impact detection prohibited section ends after a pre-determined term (T1) has passed since the hand-driven state has been switched to the non-hand-driven state. For the load compensation controlling circuit 125, the signal lines AA, BB are both open in a load compensation detecting section, and a current generated by a counter electromotive force is allowed. At the same time, the transistors 153, 154 are made ON and caused to have a potential of VDD, and a voltage generated by a counter electromotive force on one path is detected by the inverters 155, 156. Thus, whether the rotor 162 of the step motor 105 has been rotated is detected. Thus, after outputting a hand-driving pulse, the signal S16 is output for several milliseconds and detection of rotation is executed.

[0044]

Fig. 6 is a timing chart showing the state of a signal at each unit in the hand-driven state. The hand-driven state is constituted of, in the order from the start of the driving of hands, a section for starting from a stationary stable point (term T2: see also Fig. 5), a driving pulse generating section (term T3), a load compensation detecting section (term T4), and a section for returning to the stationary stable point (term T5). This stationary stable point is a rotational position for the rotor 162 of the

step motor 105 to be stable in a state where the rotor 162 is being provided with no driving pulse.

[0045]

The driving pulse is constituted of signals S20, S21
5 each having a pre-determined number of pulses for which the controlling circuit 102 orthogonally intersects the transistors 133, 134 as shown in Fig. 6. This driving pulse is output for a pre-determined time period (for example, 6 ms) after the section for starting from a
10 stationary stable point (term T2) has passed. Because the signal lines AA, BB are open before outputting the driving pulse, the rotor 162 of the step motor 105 starts to rotate from an unstable position that is not the stationary stable point when the driving pulse is provided suddenly. By
15 providing this term T2, the rotor 162 can be pulled back to the stable stationary point. By providing this driving pulse, the waveform of the current flowing in the step motor 105 is varied as shown in Fig. 6. After the driving pulse generating section (term T3) has ended, the waveforms
20 of the current on the signal lines AA, BB are varied as shown in Fig. 6 to be converged. During the load compensation detecting section (term T4), the output S16 is output from the load compensation controlling circuit 125 to detect a counter electromotive force from the step motor
25 105. After this, the hand-driven state ends after waiting for the passage of the section for returning to the stationary stable point (term T5).

[0046]

Fig. 7 is a timing chart showing the state of a signal
30 at each unit when a light impact has occurred during the non-hand-driven state. When the state of the second hand is switched to the non-hand-driven state, the signal S18 is at [H], the signal S19 is at [L], the signal S10 is an

alternating signal having the period of 1 ms and the chopper width of $30.5\ \mu\text{s}$ that is the term for [L] state, the signal S20 is at [H], the signal S21 is at [L], the signal S15 is at [H], and the signal S16 is at [L].

5 [0047]

It is assumed that a light impact is applied during the term t_5 in this state. In this case, the waveform of the current is varied as shown in Fig. 7. The waveform of the current is amplified with the signal S10 that is the
 10 chopper-amplification. Thereby, as shown, even when the level of the waveform of the current generated due to the light impact is low, the level is chopper-amplified, and the peak value thereof is made high and exceeds the threshold value in a short time period from the occurrence
 15 of the light impact. Therefore, the impact can be detected. The details of the chopper-amplification will be described later.

[0048]

The threshold value being set in the inverters 145,
 20 146 of the impact detecting circuit 104 is a voltage that is a half of V_{reg} ($V_{\text{reg}}/2$) that has been defined as a constant voltage. When the induced electromotive force of the coil 161 of the step motor 105 exceeds this threshold value due to the application of the light impact (term t_6),
 25 the impact detecting signal S33 is output to the lock pulse controlling circuit 122. The lock pulse controlling circuit 122 makes both of the signals S18, S19 at [H] that the circuit 122 provides to the transistors 131, 132 provided to the signal line AA, and outputs the lock pulse
 30 (the waveforms of the currents on the signal line BB is varied from [H] to [L]). At the same time, the lock pulse controlling circuit 122 varies both of the signals S20, S21 from at [H] to at [L] that the circuit 122 provides to the

transistors 133, 134 provided to the signal line BB. The lock pulse controlling circuit 122 also makes the signal S15 at [L]. Though the waveform of the current on the signal line BB has exceeded the threshold value in the above description, a lock pulse is also output when the waveforms of the currents on the signal line AA has also exceeded the threshold value.

[0049]

The deviation of the position of the second hand 106 is prevented by braking the second hand 106 with this lock pulse. This lock pulse brakes (stops and holds) the second hand 106 in the form of pulling back the rotation of the second hand 106 (rotor 162) by applying a pulse having the same phase as that of the driving pulse after detecting an impact. Thereby, control to correct the motion of the second hand 106 (rotor 162) is not necessary after this motion.

[0050]

As shown in Fig. 7, the lock pulse section T6 is set to be, for example, 1 ms and supplies a continuous [L] level (lock term T6a) to the coil 161 of the step motor 105 through the signal line AA. Corresponding to the lock term T6a of the lock pulse section T6, the impact detecting resistor controlling circuit 126 maintains the waveform of the signal S15 at [L] and prohibits the detection of impacts. A stable section T6b is provided after the lock term T6a and, during this lock term T6a, the signals S18, S19 are supplied with the waveforms thereof switched to [L] to the transistors 131, 132 after the lock pulse has been supplied. An insensitive section T6c is provided after the stable section T6b and, during this section T6c, the waveform of the signal S18 is restored to [H]. Thus, as shown in Fig. 7, the fluctuation of the waveform of the

current can be converged in the lock pulse section T6.

[0051]

Fig. 8 is a timing chart showing the state of a signal at each unit when a heavy impact has occurred in a duration of the non-hand-driven state. Compared to Fig. 7, the state of the signals at each unit in Fig. 8 is approximately same. However, because this is a case of a heavy impact, the impact can be detected in a shorter time period than the light impact. When a heavy impact is applied during the time t5, the waveform of the current is varied such that the waveform exceeds the threshold value in a short time period as shown in Fig. 8. Thereby, when the current in the coil 161 of the step motor 105 has exceeded this threshold value (time t6) due to the application of the heavy impact, the lock pulse controlling circuit 122 switches the states of both of the signals S18, S19 to [H] and outputs a lock pulse. Each signal state after this is same as that of Fig. 17 and description for this is omitted.

20 [0052]

Fig. 9 is a waveform diagram of a current detected when a light impact is applied. When a light impact is applied at time t5, the waveform of the current in the coil 161 of the step motor 105 may not exceed a threshold value V_{th} for detecting an impact as shown in Fig. 9 because the level of the impact is low. Thereby, an impact may not be detected and a lock pulse can not be output when a light impact has been applied.

[0053]

30 Fig. 10 is a waveform diagram of the current obtained by chopper-amplification when a light impact is applied. Similar to Fig. 9, a waveform of a current is shown that is obtained when a light impact is applied and is chopper-

amplified by the chopper-amplification waveform shaping circuit 118. As shown, by chopper-amplifying at a pre-determined period (1 ms in the shown example), the value of the current generated when the light impact is applied exceeds the threshold value V_{th} set in the inverters 145, 146 for detecting impacts and the impact can be detected at time t_6 .

[0054]

Fig. 11 is a chart showing an example of settings of the relation between the period and the chopper-width during the chopper-amplification. For chopper-amplification, the period and the [L]-term that is the chopper-width are respectively set at, for example, 1 ms (1 kHz) and 30.5 μs . Especially, the [L]-term that is the chopper-width is set at a reference period having the shortest period (fundamental frequency) that can be set for a timepiece. Problems have arisen that the detecting section becomes short if this term is larger than 30.5 μs and that chopper-amplification becomes impossible if this term is smaller than 30.5 μs . Why the period is set at 1 ms is to detect an impact before the peak voltage is exceeded by setting the period to be a term that is shorter than the interval (for example, 2 ms) of the counter electromotive force caused by the impact. Besides, the period is set at 1 ms because the interval created when the impact is applied may be shorter, and because the power consumption by the gate electrostatic capacities of the P-MOS transistors 135, 136 used as drivers are increased if this period is set to be shorter than 1 ms.

[0055]

The amplification ratio of the chopper-amplification can be set or adjusted at an appropriate value for each

type of timepiece (for example, the weight, the biased weight, and the size of the second hand 106) or for each individual timepiece. The period can be made variable corresponding to the power source voltage and, in this case, impacts can be stably detected coping with the variation of the power source voltage.

[0056]

For the lock pulse, the pulse width can be varied by the power source voltage and the lock pulse can be output with the most efficient pulse width for the power source voltage. This lock pulse can brake the second hand 106 by making the lock pulse a pulse having a larger term than (for example, twice as large as) that of the driving pulse in the hand-driven state. To let the output of the lock pulse precede avoiding the detection timings of the above BD (battery power source voltage detection) and the DF adjustment (logic frequency adjustment), impacts can be detected preceding other processes when the deviation of the second hand 106 in the non-hand-driven state is prevented.

[0057]

Fig. 12 and Fig. 13 are respectively explanatory charts for the relation between the power source voltage and the deviation of the displayed time in the configuration of the present invention. In these drawings, the resistance values of the impact detecting resistors 141, 143 are respectively 5 k Ω ; the stable term T6b of the lock pulse is 5 ms; and the insensitive section T6c is 1 ms (see Fig. 7). Fig. 12 differs from Fig. 13 in that the lock term of the lock pulse of Fig. 12 is 5 ms and the lock term of the lock pulse of Fig. 13 is 10 ms. These charts respectively have the axis of abscissas representing the height of fall and the axis of ordinate representing the

power source voltage (the voltage applied to the coil 161 of the step motor 106).

[0058]

As shown in Fig. 12, when the lock term of the lock pulse is 5 ms, regardless of the height of fall, a deviation of time of a two-second delay of the displayed time is generated for most of the power source voltages equal or below 1.5 V to 1.25 V. Whereas, as shown in Fig. 13, when the lock term of the lock pulse is set at 10 ms, no deviation of the displayed time is generated for all the heights of falls even when the power source voltage is set at any power source voltage from 1.8 V to 1.25 V. In this manner, a deviation of the displayed time can be solved by setting the lock term of the lock pulse at an appropriate value.

[0059]

When the power source voltage is relatively high (for example, 1.8 V to 1.6 V), a setting that shorten (for example, shorten from 10 ms to 5 ms) the lock term of the lock pulse is possible. Because of this, the controlling circuit 102 can be adapted to vary the lock term in response to a power source voltage of the battery detected by the BD controlling circuit 117, etc. For example, lock terms optimal for power source voltages may be set in advance in a storage unit, not shown, in the form of a table, etc., and a lock term corresponding to a detected power source voltage may be read from the storage unit and may be used.

[0060]

As described above, according to the first embodiment of the present invention, whether the impact applied in the non-hand-driven state of the second hand is a light impact or a heavy impact, this impact can be detected and the

deviation of the second hand can be prevented. Therefore, the correct time can be displayed. Because impacts can be detected with high precision, the second hand can be braked without increasing the retention torque of the step motor, and reduction of the power consumption necessary for the braking of the second hand, needed when an impact is detected can be facilitated.

[0061]

(Second Embodiment)

Fig. 14 is a block diagram showing the configuration of an analog electronic timepiece of a second embodiment of the present invention. Same reference symbols as those in the first embodiment are respectively given to the same components in the second embodiment that have the same configuration described using the first embodiment. In this second embodiment, the impact detecting resistor and the load compensation detecting resistor that are provided separately in the first embodiment are provided as one detecting resistor acting as those two resistors. The signal line AA is provided with a detecting resistor 1201 and a transistor 1202. The signal line BB is provided with a detecting resistor 1203 and a transistor 1204. Similarly to the first embodiment, the resistance values of the detecting resistors 1201, 1203 are set at the lowest value with which the fact that the rotor 162 of the step motor 105 has rotated due to an impact can be detected (for example, in a range of 40 k Ω to 160 k Ω). The detecting resistors 1201, 1203 may be adapted to be variable resistors and to be able to switch the resistance values thereof between a resistance value suitable for the time when an impact is detected (for example, 40 k Ω) and a resistance value suitable for the time when load

compensation is detected (160 k Ω).

[0062]

The signal S15 output by the impact detecting resistor
controlling circuit 126 and the signal S16 output by the
5 load compensation controlling circuit 125 are connected
with the transistors 1202, 1204 through an OR circuit 1205
and are controlled respectively at the timing when an
impact is detected and when load compensation is detected.
The impact detecting signal S32 output by the impact
10 detecting circuit 104 is output to the load compensation
controlling circuit 125. A signal S51 output by the impact
detecting resistor controlling circuit 126 is output for
selecting whether the load compensation controlling circuit
125 is caused to act for load compensation as described
15 above or to act as the lock pulse controlling circuit 122.
The load compensation controlling circuit 125 acts as a
load compensation controlling circuit in the hand-driven
state and determines whether this circuit 125 outputs the
signal S27; and acts as a lock pulse controlling circuit in
20 the non-hand-driven state and determines whether this
circuit 125 outputs a signal S53. In the configuration of
the second embodiment, the signal state of each unit is
same as that of the first embodiment and the second
embodiment has a same impact detecting function.

25 [0063]

According to the configuration of the second
embodiment described above, similarly to the first
embodiment, whether the impact applied in the non-hand-
driven state of the second hand is a light impact or a
30 heavy impact, this impact can be detected and the deviation
of the second hand can be prevented. Therefore, correct
time can be displayed. Because impacts can be detected
with high precision, the second hand can be braked without

increasing the retention torque of the step motor, and reduction of the power consumption necessary for the braking of the second hand, needed when an impact is detected can be facilitated. The number of resistors for the detection of impacts and detection of load compensation, and the number of transistors to be driven can be reduced, and reduction of the number of circuit elements, the costs, and the space can be facilitated.

[0061]

As described above, according to the present invention, an impact can be detected in the non-hand-driven state of the second hand, a deviation of the second hand can be prevented, the time can be correctly displayed, and the second hand can be braked when an impact is detected regardless of the thickness, the size, the weight, the biased weight of the second hand. Therefore, the visibility of the displayed time can be improved by employing a larger second hand. Restrictions on the design of the second hand can be alleviated and incorporation of various designs can be facilitated.

[0064]

The controlling method for the time when an impact is detected described in this embodiment is realized by a random logic. However, the method can also be realized by executing a program prepared in advance on a computer constituting the controlling circuit. This program is recorded in a computer-readable recording medium such as a hard disk, a flexible disk, a CD-ROM, an MO, a DVD, etc., and is executed by being read from the recording medium by the computer. This program may be a transmission medium distributable through a network such as the Internet, etc.

INDUSTRIAL APPLICABILITY

[0065]

As described above, the analog electronic timepiece of the present invention is useful as an analog electronic timepiece having time hands capable of preventing a
5 deviation of the time even when an impact is applied, and is particularly suitable for a wrist timepiece, etc., that is likely to receive impacts applied due to falling or colliding with objects because the timepiece is used being worn by a user.